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The Colorado Canyon

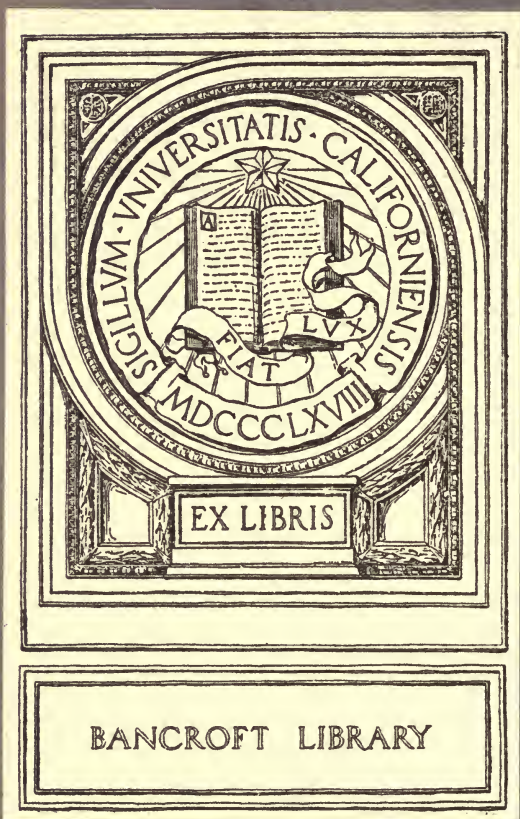
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THE COLORADO CANYON—SOME OF ITS LESSONS.*

By Prof. W. M. DAVIS, of Harvard University.

THE Colorado canyon, deeply eroded by the Colorado river in the arid plateaus of northern Arizona, was first scientifically described by Newbery fifty years ago; ten years later it was explored by Powell in

* Summary of lecture at the Royal Geographical Society, March 22, 1909.

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his famous expedition down the river in boats; since then it has been elaborately described by Dutton and impressively pictured by Holmes in the second monograph of the United States Geological Survey; it is now accessible by rail in four days from New York, and is annually seen by many thousand visitors. Most of these visitors still fancy that the canyon was first suddenly formed as a huge fracture, through which the river then took its course; but there is absolutely no evidence that such is the case. A number of fractures do traverse the plateau district from north to south, but the river, flowing from east to west, pays no attention to them. The canyon is purely the work of normal erosion. When the visitor is assured of this, his first thought is that the river has done an enormous piece of work in eroding so huge a canyon. Truly the erosion of a canyon is a great work, and yet it is only a respectable beginning of the work upon which the river has entered. When the visitor is told that the completion of this work involves the slow erosion of the vast mass of the plateaus north and south of the canyon, he becomes incredulous. When it is sought to explain that so great an amount of erosion has already repeatedly taken place in the Earth's history, and that some geographers propose to make use of what has been learned about erosion, by describing all land-forms in terms of the stage that they have now reached in the entire cycle of erosion upon which they have entered, the visitor is inclined to regard such a method of geographical description as too fanciful for practical application.

Nevertheless, if a visitor of ordinary intelligence, though without technical training in geology or geography, after looking attentively at the rock structures displayed in the canyon walls, and at the plateau forms north and south of the canyon, will but listen patiently to the explanations that have been found for what may there be seen, he must be convinced that the enormous work already done by ordinary erosional processes is only a good beginning of a far greater task, and in the end he must be satisfied that the description of all land-forms in terms of the stage that they have now reached in their cycle of erosion is not only feasible but effective. He will at the same time learn a lesson that is most valuable to all geographers, namely, that the present epoch of Earth history, with which geographers deal, is merely the latest epoch added to a long series of very similar preceding epochs; that geography is only the to-day that follows the yesterday and the many earlier days of geological reckoning; and that the contrasts which characterized the older-fashioned study of geography and geology are, in the modern understanding of Earth science, largely replaced by resemblances.

The first lesson to be learned during a visit to the canyon is, therefore, the efficacy of ordinary erosional processes of the present day, even in the dry climate of the plateau region. When this fact of

observation is appreciated, the geographer must use his imagination as to past and future erosional work. He must first recognize that the main canyon, 100 miles long and nearly a mile deep, and its innumerable side canyons, have been carved in the plateau by the main river and its wet-weather branches. He must then strive to realize that the indefinitely long continuation of these processes will eventually consume the entire plateau, and reduce it to a nearly featureless lowland, but little over sea-level. He must open his mind to the conception of these possibilities, which are logically based on the long continuation of present conditions in the past and the future. He is then really prepared to apprehend that the canyon, as we see it to-day, is simply a modest beginning in the vast task that nature has assigned to the Colorado river—the task of cutting down its channel, and of receiving and carrying away to the sea all the rock waste weathered and washed from the plateaus, until the plateaus are worn down to lowlands. Great as the canyon is, it is only a young valley. Vast as may be the work already accomplished by the energetic river, this work is only a fair beginning in the enormous task that the river has undertaken.

It is not to be wondered at, if a beginner in Earth science finds it difficult to imagine the actual accomplishment of so great a task as the removal of the broad plateaus by the slow processes of weathering and washing. Even Colonel Greenwood, who sixty years ago attributed so much work to rain and rivers, did not venture to state so extreme a conclusion that, after the valleys are carved, the hills must be worn away. True, Ramsay had somewhat earlier perceived that the long-continued action of seashore waves, supplementing the action of subaërial erosion, would eventually produce a "plain of marine erosion;" but it was the American explorer and geologist, Powell, who first brought forward the view that a plain of erosion may be produced without the aid of marine processes; and the very facts which led Powell to this view are seen in the walls of the Colorado canyon. Let us therefore look at the structure of the plateau as it is revealed in this great natural section.

In the eastern part of the canyon, where the altitude of the plateau is of moderate measure, the entire depth of the canyon is cut through a series of horizontal strata, which we may call the plateau series. Further west, where the plateau is higher and the canyon is deeper, the strata of the plateau series are seen to rest on an even foundation of crystalline rocks. Hence the history of the plateau may be treated in two chapters. Between these two localities, a series of slanting strata, inclined to the eastward with a dip of about 20° , lies between the crystalline foundation and the plateau series; these inclined strata may be called the "wedge series," because they seem to be wedged in between the other two rock series; thus it is perceived that the

history of the plateau may be divided into three chapters, each of which has been occupied in making a member of the rock series.

By descending to the canyon bottom, the contact surface, where the slanting wedge series lies in the slanting crystalline floor, may be examined. The first conclusion there gained is, that the present slanting separation surface of these structures must have been horizontal at the time of the deposition of the wedge series. The second conclusion is that the crystalline floor, a remarkably even surface, must have existed as such before the deposition of the first member of the wedge series. What was the origin of the level-topped crystalline mass?

Crystalline rocks cannot be formed on the land surface or at the sea bottom; they originate at a significant depth beneath the surface, under conditions of high temperature, great pressure, and long time. The structures of this crystalline mass are varied, and have not yet been studied in detail; but it cannot be doubted that the first chapter of the history of the region, in which these ancient rocks were formed, was a very long chapter.

If the crystalline rocks were formed at a considerable depth in the Earth's crust, the overlying parts must have been removed by erosion in order to lay bare the deeper parts. Hence we perceive that a chapter of erosional work must be interpolated between the making of the crystalline rocks and the deposition of the wedge series. The crystalline floor on which this deposition took place is remarkably even; hence during this interpolated chapter, an entire cycle of erosion must have run its course; and such a cycle is a vastly longer period of time than that required to erode a mere canyon. A canyon represents a good beginning in a cycle of erosion; a floor of crystalline rocks, worn down to a plain, represents the actual attainment of the end of a cycle of erosion. And only after this long-delayed end was attained did the deposition of the wedge series begin.

The deposition of the wedge series, the third chapter in the history of the region, implies slow depression (and presumable submergence) of the worn-down crystalline mass, and the erosion elsewhere of the materials here deposited. The wedge series is about 2 miles thick, and although part of it consists of ancient lavas, its sedimentary content is enormous. To supply so much material by the erosion of some neighbouring area must have again required a long period of time.

Then came the tilting of the wedge series and the underlying crystalline rocks, and the erosion of the tilted mass until it was worn down to the even surface which now transects both the crystalline rocks and the wedge series. Here again a new chapter, the fourth in the history of the region, must be interpolated between the making of the wedge series and the making of the plateau series; and, like the previous chapters, this one must have been enormously long, because it again witnessed the essential completion of a cycle of erosion.

Then, in a long fifth chapter, came the slow depression and submergence of the worn-down mass, and the deposition of the plateau series. Its lower members are of Cambrian date; its upper members are Carboniferous. Hence it would seem as if the erosion of the canyon had occupied the time from the Carboniferous period to the present; but this is far from being the case.

If we now travel northward across the plateaus, we shall find at a distance of 50 or more miles a series of south-facing cliffs, where one may gradually ascend by a succession of great steps to the high plateaus of Utah. Here is a heavy series of strata, from Permian to Eocene in date, and all in essentially conformable sequence, with a gentle inclination to the north; and there is good reason for believing that these strata once stretched far southward across the Arizona plateaus, even beyond where the canyon is now eroded. The deposition of this uppermost series required a sixth chapter, and its removal from the Arizona plateaus a seventh chapter, each of which must have been vastly longer than the time required for the erosion of the canyon; and only after the seventh chapter was far advanced was the region elevated to its present altitude, and the erosion of the canyon begun.

What, then, are the lessons of the canyon? Not simply that it is a grand example of patient work, but that as a consequence of its erosion, the deep structure of the plateau is revealed, and that this structure proves to us the long continuity of processes like those of to-day through many chapters of past time, each of which was much longer than the few pages required for the erosion of the canyon; not simply that these processes have acted through long-past ages, but that some understanding of them is essential for an appreciation of the present; not simply that the canyon is the work of normal erosion, but that the canyon may reasonably be described as a young valley, as the work of normal processes during the early part of a cycle of erosion, which, if continued, will witness the reduction of the plateaus to lowlands, similar to the lowlands of erosion that were produced in the second, fourth, and seventh chapters of the region's history. There is, therefore, nothing unwarranted in the use of an explanatory description for land-forms, in terms of the stage that they have reached in the cycle of erosion upon which they have entered. Such a method of description simply makes use of the well-attested occurrences in Earth history as a means of describing its present condition.

The PRESIDENT (before the paper): The lecturer whom we welcome here to-night is Prof. Davis of Harvard University—a university in which I think we have a special interest, as it was founded by a Londoner. Prof. Davis has, I think, done more than any man on either side of the water to raise the standard of the teaching of geography in the direction of making it a more definite science. I am sure, after you have heard his lecture to-night, you will not be surprised to know that his

teaching is of a peculiar stimulating nature, and that amongst his pupils there are many who have already won considerable distinction in geography. I may perhaps mention the name of Dr. Ellsworth Huntington, who wrote the 'Pulse of Asia,' and who has lectured to us here. We owe to the system of exchanges of Chairs between Harvard University and Berlin the pleasure of the visit to-night of Prof. Davis, because he is on his way back from having fulfilled his duties in Berlin, having made such an exchange with a German professor. I cannot help hoping that this system of exchanges of Chairs which exists between Harvard and Prussia may find an echo in this country, and that at some future time we may frequently welcome American professors, not only as our guests, but as our teachers.

The PRESIDENT (after the paper): I think we shall all carry away a considerable number of vivid memories of to-night's lecture. We shall all retain recollections of the extraordinary beauty of the scenery of this Colorado valley, and of the admirable way it has been illustrated. But I believe there are other and more permanent memories which will remain in our minds. Every one who has ever looked at a bit of scenery and had in his mind at the time a knowledge of the geological formation of the country, must have been struck with the way the interest of the scene is thus enhanced. I take it that our lecturer to-night has wished to indicate to us that by teaching the origin of land-formation we arrive at far the best method of geographical description. He has, in fact, without our knowing it, been giving us a lecture on the best form of geographical teaching; and I am sure I may express your wishes that many other such lectures may be given us, affording educational instruction in such a pleasing manner.

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